RESEARCHES ON THE DEEP-SEA FAUNA FROM A ZOOGEOGRAPHICAL POINT OF VIEW

DURING recent years surprising and very remarkable discoveries have been the result of expeditions despatched from various countries by official and private bodies, in order to examine the zoological condition of the oceans of the globe. Thus, below the line of three hundred fathoms' depth, where biologists for many years believed with Edward Forbes that all animal life ceased, a fauna rich both in forms and individuals has been brought to light, and the theories once common enough among *savants* of a total absence of life at a certain depth in the sea have thereby in two decades suffered a complete revolution. Many objects which had previously been looked upon as biological impossibilities have been discovered, and the systematic science of zoology has been enriched with copious materials, from which hitherto unknown animal varieties have been described, recorded, and placed in their true position in the system, whereby many a gap in the zoological scale has been filled up, and science in a remarkable space of time made rapid progress. Besides this merely scientific gain, which can only be fully realised by men of science, the zoological museums have obtained valuable and fruitful treasures. The researches of the fauna of the oceans have been of double advantage, viz. as both enriching science and museums, and zoologists are delighted at both. The interest which various countries have taken in the study of the fauna of the sea has been shared between England, the United States, Sweden, Norway, and Holland, while lately even France and Italy have taken steps to assist in promoting this branch of biology, and there can be no doubt that similar researches will in the immediate future be carried on as indefatigably as heretofore.

It is my intention, with this prospect in view, to point out in these columns some methods of research in studying the fauna of the sea, which I believe will be of great advantage to science.

The manner in which the dredging of the sea is carried on from a vessel is generally this. The deposit on the bottom which the trawl or other similar appliance brings up is carefully sifted, and its animal contents placed in suitable vessels filled with spirits or other fluid for preservation. If time serves, a sorting of the various objects takes place at once, so that animals of various groups are deposited in separate vessels. These latter are either fully marked or else simply ticketed with a number, which is interpreted by an entry in the "dredging-log" kept for that purpose. The object of this log is, in the first instance, to fix exactly the spot—latitude and longitude—where the sample was taken, the time of the capture, the condition of the bottom, the depth, the temperature of the water, and if possible also the contents of salt both at the depth from which the sample was taken and at the surface. These are the annotations which have up to the present time been made by scientists when dredging. When the samples or collections thus obtained reach *terra firma* their scientific examination commences, and it becomes a matter of great moment to extract from these laboriously collected fragments a scientific whole which will be of value to zoology. The various groups of animals are consigned to different hands, *i.e.* taken in hand by specialists, the result of whose researches will naturally vary according to the lines of study they pursue. In nearly every instance the result of the same is a descriptive or anatomical work, as well as a work of the fauna; varieties and forms new to science are described, delineated, and placed in their true position in the system, while some previously known are shown to exist in places where they had hitherto been unknown. Science has thereby made a double gain, viz. a systematic and a zoogeographical. With regard to the systematic gain, it is no doubt considerable. The descriptions, with or without illustrations, may be long or short, and refer either to the exterior forms or interior construction, *i.e.* its anatomy in a limited sense; still they are invariably fruitful if they are only sufficiently complete and, what is of most consequence, methodical. Both anatomy and morphology will in most instances obtain from them what is demanded by these sciences. But on the other hand the zoogeographical gain is very unsatisfactory. What do we thus, for instance, learn from such a statement as this, that *Yoldia arctica* has been met with in lat. 73° 0′ north, and long. 68° 15′ east? Nothing more nor less, in fact, than that it has been found in this particular place along with many others. By comparing, however, this locality with the others where it has previously been found, I no doubt gain a certain knowledge of its horizontal distribution, but I do not in the least degree learn from this statement the laws which govern the same. If, on the other hand, I am informed that the bottom in the place of discovery is brown sand mixed with clay, that the depth is eight fathoms, that the temperature of the water was $-2°$ C., and its specific weight 1·0273, I have at once materials for a far wider knowledge. These particulars furnish me with a basis for ascertaining the external conditions which regulate the existence of this species; and if I, besides these particulars, also learn with what animals of the same and other genus the *Yoldia* has been found in that particular place, I obtain a certain imperfect idea of the animal life existing there. I said imperfect, as, in order that the description should be complete, it is necessary I should also know the number of each species found. If I had thus information of how many individual *Yoldia* were taken in this place, and how many of the other species of animals were taken, and also if specimens of *every one* of the animals existing in this place had come up in the trawl, then I should possess an approximate knowledge of the animal fauna existing in such a place. The knowledge of the relative number of the species in a certain place is, in my opinion, a factor of essential importance to the science of zoogeography.

The example I have just quoted shows sufficiently how very incomplete the zoogeographical statements are which only record the exact place where certain species were taken. On such a basis nothing of any scientific value can be founded.

It would, I consider, be of immense value to zoology if dredgings during the larger expeditions were effected by men skilled in every branch of this science. It is clear that the more copious and varied the knowledge of the zoologist is the greater will the gain be to science on this point, especially if the student is able at the moment to take full note of what is brought to the surface. If this be the case, he would be able there and then to classify the varieties caught and particularly record the number of individuals taken, which is naturally of most consequence where it is not possible to preserve all species. Such records would be of great value to students of zoogeography, and I am under the impression that as yet no zoologist has conceived this idea, or at all events not carried it into execution.

It would undoubtedly be a matter of some difficulty, from the copiousness of the existing zoological literature, and the consequent impossibility of mastering the same, to find men who are experts in every branch of descriptive zoology, and at the same time prepared for such work as I have indicated here. While the mere mechanical act of dredging must necessarily be effected by younger men, the careful sifting of the deposit brought up is of such importance that it should only be done by a zoologist of advanced years and study; but as it seems an impossibility to combine the two conditions, the only possible way out of the difficulty is for the zoologist to preserve all which comes up if the material shall be of any use to zoogeography.

Having indicated my views in general on this subject, I will proceed to state those cardinal points of which the zoologist should always give exact and as detailed particulars as possible, which I consider essential to the development of zoogeographical science. They are :—

1. *Place of Discovery.*—This should preferably be fixed by latitude and longitude, but, if this is not possible, by other exact means. In works describing certain sea fauna I have often found expressions as vague as these: "Bohuslän (province of Bohus)—Bergen," or "Kullen—Finmarken," "Norway and Greenland." The former of these descriptions may be satisfactory enough, if thereby is meant that the species in question are to be found between Bohuslän and Bergen, and from Kullen to Finmarken, although it would have been of more value if, even with the commonest kind, *each* place of discovery had been enumerated. It is a well-known fact that both common and rare species alike are found in smaller or larger quantities in different places, and it is information of this circumstance which it is necessary to have if a student shall be able to determine the horizontal extension of a certain species and its numerical relation to others within a certain area. With regard to the latter it implies, I suppose, that the species in question may be found along the whole coasts of Norway and Greenland, but the real meaning is, however, that they have been found somewhere, perhaps in several places, within the specified limit, and information of such vague character is to say the least of it imperfect. The physical conditions of the coasts of Greenland below the level of the sea *may* be the same from the most southern to the most northern point, but, on the other hand, it must not be forgotten that the known extent of Greenland from south to north is 23 degrees, *i.e.* 345 geographical miles, and that it is, therefore, just as likely that what applies to the development of the fauna in Davis Sound does not apply to that in Baffin's Bay; less still in Smith's Sound, not to mention that of the east coast. The extent of Norway covers 11·5 degrees, or 172 geographical miles, and the physical conditions around the coast are very variable, and as regards the fauna of the sea here it is a fact that there is a great division in the southern and the arctic element.

An exact fixing of the place of discovery has only been quite recently effected. Thus, K. Moebius's work, "Die wirbellosen Thiere der Ostsee," F. Meinerts's "Crustacea isopoda, amphipoda, et decapoda Daniæ," and A. W. Ljungman's "Förteckning öfver Spetsbergens Holothurider" leave nothing to be desired in this respect; but these cases are only exceptional, as most zoologists, whether treating the anatomy or the fauna, are satisfied with a mere enumeration of places of discovery. It is, however, true that zoological literature, as well as all other, deals with many extraneous matters, while some writers are anxious to adopt a very brief style; but in the matter of detailing the place of discovery no brevity should be observed. If zoogeography is to be something more than a mere knowledge of the horizontal distribution of the species, the places of discovery must be exactly detailed.

2. *The Depth.*—The depth at which the sample was taken should also be exactly stated as, while the place of discovery teaches us the horizontal distribution of a species, the depth indicates the vertical one. It is a well-known fact that most species are confined within certain vertical limits, which are in some instances not far apart. It certainly was to be expected that information of this nature would be found in modern works, but this is not the case. G. O. Sars' "Mollusca regionis arctica Norvegia," F. Meinerts's above-mentioned work, and O. Harger's "Report on the Marine Isopoda of New England and Adjacent Waters" are, however, remarkable exceptions to this fault. The accuracy and minuteness of these authors on the vertical distribution of the species deserve every commendation, while it must be regretted that such a work as A. Boeck's "De skandinaviske og arktiske Amphipoder," which is undoubtedly the fruit of many years' practical study and research, gives in most cases no account whatever of the vertical distribution of a species. One attempts thus, for instance, in this work unsuccessfully to learn within what limits such a common species as the *Gammarus locusta* occurs on the Scandinavian coast. R. M. Bruzelius, in his work, "Skandinaviens amphipoda gamonaridea" (1858), and A. Göes, in his "Crustacea amphipoda maris Spetsbergiam allnentis, &c." (1865), had both set excellent examples in the way of describing the distribution of species in the deep; still Boeck has paid no attention to this important question. He has only dealt with the synonymy, genus, and the horizontal occurrence of the species, and even as regards the latter his statements are very summary. With such statements as these, that *Diastylis Rathkei* has been found between 3 and 540 fathoms, *Idothea Sabieni* between 4 and 1215 fathoms, *Axinus flexuosus* between 3 and 450 fathoms, *Xylophaga dorsalis* between 10 and 650 fathoms, and *Caryophyllia Pourtalesi* at 100 and 980 fathoms depth respectively, it may at first sight appear a matter of little importance to state at what depth they have in each individual case been found. This is, however, one of great importance. The vertical distribution of species is variable in different seas, and it must depend on subsequent research to determine on what this variability depends. The causes may be several, and are no doubt complicated ones, as the pressure of the water, which for a long time was considered one of them, does not in any way affect their existence. The causes must be of a very different nature, and before any of them can be ascertained it is necessary to obtain exact particulars of individual instances. The following comparison of the vertical distribution of a few species in various seas may illustrate this :—

Tellina solidula appears in the Arctic waters of—

	Novaya Zemlya	Norway
	at from 4- 26 fathoms	at from 0- 10 fathoms
Cardium ciliatum	,, 2- 60 ,,	,, 5- 10 ,,
Cardium grönlandicum	,, 2- 20 ,,	,, 5- 10 ,,
Rhynchonella psittacea	,, 5- 60 ,,	,, 20- 80 ,,
Margarita obscura	,, 2-120 ,,	,, 120-300 ,,
Fusus tornatus	,, 8- 10 ,,	,, 20-100 ,,

The difference in five of these cases is not very great, but in one—*Margarita obscura*—it is very considerable, and even if we are unable to explain it, it should nevertheless be recorded.

3. *The Nature of the Bottom.*—This is a factor of great moment in the fauna of the sea and the division of the species. I have thus on the coast of Novaya Zemlya and in the Siberian seas personally observed that a clean sand bottom without admixture of clay is very poor in fauna, but if mixed with some clay somewhat richer, while where the clay predominates it is greatly richer. The most copious and varied is, however, that of the pure clay bottom. In shallow water on the coasts of Scandinavia the student has many opportunities of observing the variations in the copiousness of the sea fauna, both as regards the numerousness of the species and their individuals on bottoms of various natures. Possibly the nature of the bottom at greater depths, below the line where the higher orders of Algæ cease to exist, is not of such influence as above the same, but that it is in most instances of great moment to the fauna I am firmly convinced. To animals which do not live on prey the quantity of the organic elements in process of decomposition in their place of vegetation must be of consequence; to most of them the organic composition

of the bottom must be of the greatest consequence. The colour of the bottom does also, I believe, affect the existence of certain species. I therefore recommend that the nature of a bottom is not *alone* recorded, as, for instance, thus, "clay bottom," "clay mixed with sand," "stones with Algæ," and "globigerina ooze," but that a sample of the bottom is also in every case taken for future chemical analysis. It should, however, be seen that the sample is from the surface layer, and not from those below, which may of course be of a quite different nature.

4. *The Temperature and Saltness of the Water, as well as its Chemical Composition near the Bottom.*—Particulars of these circumstances should always be given exactly, as they do, no doubt, have a considerable share in the production of a species. This is so evident that it requires no further discussion.

5. *The Period of the Research.*—This is a point which zoologists in most instances fail to record, and yet it appears to me in several respects to be of great interest. Everything in life is subjected to a gradual organic change, and I believe that the fauna of the sea in this respect does not differ. Those species of animals which to-day appear within a certain locality are undoubtedly not the same which were found there, say, a hundred years ago, and still less the same as those which existed there a thousand years ago, and what applies to the past applies with equal force to the future. The struggle for existence causes the immigration of new forms, while others must, so to say, make room for the newcomers and thereby disappear. This lies in the progress of historical development. For this reason it is necessary to state the period of the research, and although science may have no immediate gain from such dates, it will no doubt come in course of time, and it is the duty of the student of zoogeography to work as much for posterity as for the present. It is with these particulars as with those of meteorological observations, viz. that one must possess a number of observations, extending over a long period, before the deductive result becomes of scientific value.

But apart from the ultimate benefit which may be derived in the future from these details, disputed perhaps by some, the record of the time when the specimens are taken is of great importance to modern science. It is thus well known that many of the inhabitants of the sea, not only those which possess perfect organs of locomotion, but also those which live a somewhat stationary life, undertake, during certain periods of the year, shorter or longer migratory wanderings. This is, however, as regards the lower Invertebrates, a circumstance which has been so little attended to, that hardly any information exists on this point in print. In connection with this peculiarity the records which I advocate would be of great use. The causes of the migratory movements may be very difficult to ascertain; but it is necessary in the first instance to demonstrate a fact—the explanation will follow in course of time. I have further indicated under (7) why I consider these statements as to time of such importance.

For the study of zoogeography in general it may be sufficient alone to know what species occur within a certain area, whether large or small. The student of zoogeography compares those species which are to be found either near or far from one another, he shows that some of them are common to all those parts which he has under consideration, that others belong to a few, and with these data before him he attempts to discover the causes of their appearance or absence in certain places. If possible, he takes the most recent palæontological phenomena into account too, he views the fauna of the present day by the light of the past, and obtains thereby remarkable and perhaps unexpected results.

6. *The Relative Plurality of the Individuals and the Colonies.*—It cannot, however, be denied that, should the mode of research indicated above be fruitful in some respects, it will not give a complete account of the animal life existing within a certain sphere. To obtain this it is necessary to know the relative plurality of the individuals and their colonies in every individual locality within the sphere. On this point my opinion is that, in order to understand correctly the composition of a fauna, it is not enough to know those species which it embraces, the zoologist must not be content with a mere enumeration either with or without descriptions of the various species and their distribution within a certain sphere, but he must also take into consideration the relative plurality of the individuals of each, *i.e.* he must, in other words, study the *statistics* of the species. It is clear that zoogeography must be based on these two propositions, as the science would not advance far, if it should, for the comparison of the fauna of two localities, rest on a mere enumeration of the species occurring in such localities. A case might certainly occur in which two localities could approximately possess the same species, while their fauna were very different in composition. To the student of zoogeography this is no improbability.

It cannot, of course, be demanded that the zoologist occupied in dredging should immediately record the number of every species the trawl brings up, as he must for this purpose possess special qualifications, but science is greatly benefited too by the course that, when the various groups of species are distributed for research and classification, the specialists in question in their works on the same record exactly the number of individuals taken of each species, and, with regard to animals forming colonies, also how many colonies were found in each place. When all the groups of the species had thus been dealt with, the student specially interested could compare the various species in every place investigated, and also the individuals and colonies in each, and by such a comparison we should obtain a really complete knowledge of the animal life in the locality investigated. If, however, no notice be taken of the relative plurality of the individuals, whether from want of study or attention to the importance of the point, the picture which the reader of his work obtains of the animal life in a certain locality will be very vague and unsatisfactory indeed.

7. *The Relation between Males and Females in the Same Place, and, if possible, at Various Times and Seasons.*—The attention of zoologists should, in connection with the study of the relative plurality of individuals and colonies, also be directed to this interesting circumstance, which of course is not related to zoogeography, but to biology. No doubt investigations of this relation would lead to valuable discoveries. In some species, with sexual difference, the males predominate, in others the females, while in some they are evenly balanced. Another point also of interest connected herewith is at what period of the season the process of fertilisation takes place, how long the pregnancy lasts, and when the females cast their eggs; whether these functions are confined to certain seasons or not. Investigations of this point show that in some cases these functions are regulated most punctually, but in others not, and consequently it would be a matter of great scientific interest to ascertain the relations of the species on this point. For this reason it is also of importance to state the exact time when the examination of a certain locality took place.

I consider that the points I have here discussed are the principal ones for which the zoologist should, in order to advance zoogeography, collect materials when making researches on the fauna of the sea. They form in my opinion the basis on which this science shall be founded for a higher and more extended knowledge, and if the researches I have here indicated are executed in a systematic manner and with due care, my belief is that zoogeography will in a short space of time reap excellent benefits and fruits therefrom; but here, as in every other branch of study, it is necessary to work with patience and in co-operation with others, as the labour is one demanding both time and exhaustive study. ANTON STUXBERG

Gothenburg Museum

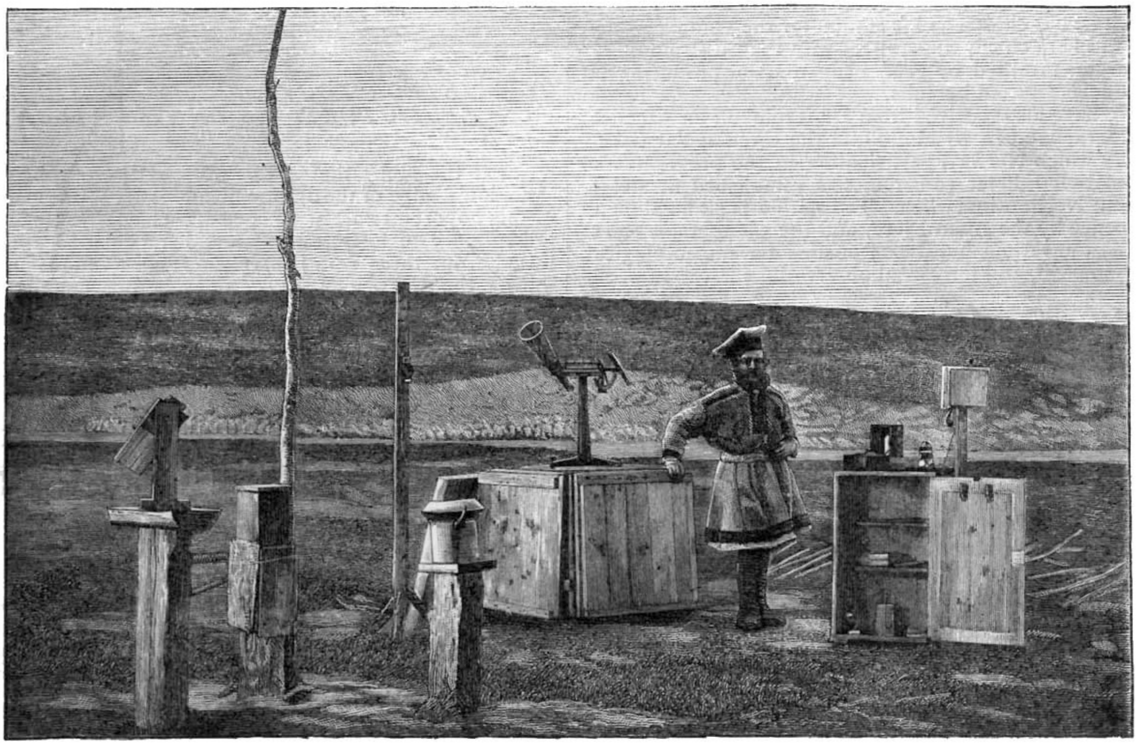
DR. TROMHOLT'S AURORAL OBSERVATORY AT KAUTOKEINO

WE are indebted to Dr. Sophus Tromholt for the photograph from which our engraving has been made of his auroral observatory at Kautokeino in Finmarken, Norway.

The Norwegian *savant* has, as may be remembered from his communications to NATURE, during last winter sojourned in Lapland for the study of the aurora borealis, simultaneously with which observations of this remarkable phenomenon have been made at the Norwegian and Finnish Circumpolar Stations at Bossekop and Sodankylä.

Dr. Tromholt writes :—" Since September last I have, for the sake of the aurora borealis, been residing here in North Finmarken (69° N. lat., 23° E. long.), in a zone therefore where the auroræ attain their maxima, and where the phenomena, consequently, are so frequent and on such a scale that there cannot be a question of selecting and analysing one in particular.

" My winter sojourn here has two objects in view, viz. firstly to frame a pendant to the observations of the aurora borealis made at Bossekop, 1838-39, by the French Commission du Nord under Lottin and Bravais ('Voyages en Scandinavie,' &c.), and, secondly, by means of altitudinal measurements corresponding with those being made at the Norwegian Meteorological Station at Bossekop, to procure sufficient materials for fixing the parallax of the aurora borealis. I choose the remote Kautokeino for my observatory for several reasons, viz. : that the place is almost due south of Bossekop, while the distance between the two is very nearly a degree, a distance which is exactly suited to the theory I have formed of the height of the aurora borealis—150 kilometres ; and also because it possesses a remarkably free horizon and an inland climate insuring favourable weather conditions.



Auroral Observatory at Kautokeino.

" As previously stated, observations are made simultaneously here and at Bossekop on a common prearranged plan, and measurements made in the same vertical plane by the so-called auroral theodolite constructed by Prof. Mohn. A similar arrangement has also been made with the Finnish station at Sodankylä, which is, however, situated at a great distance from this place, and in a direction somewhat unfavourable (about 45° S.E.). We shall not of course be able to compare notes before the spring, so I am unable at present to give the final results of my observations ; but judging by own researches here I feel convinced, in spite of scientists' assertions to the contrary, that the height of the aurora borealis may be measured by the method I advocate, and that from the observations made at these three stations we shall obtain the materials required for the solution of a problem hitherto deemed an insoluble one.

"The photograph which I forward you shows the little 'scientific temple' I have raised in these lonely tracts, which have hitherto only seen Lapps and reindeer. In the centre stands my most important instrument, viz. a combination of the auroral theodolite and the passage instrument, fixed on a stone column and inclosed in a small wooden box, the upper half of which may be lowered at will. Here are, besides the necessary apparatus for meteorological observations, also to be found every requisite instrument and appliance required for my researches, such as chronometers, spectroscopes, lanterns, &c. Between them all stands the writer himself, clad in the tasteful summer costume of a Lapp, viz. pointed leather shoes, breeches twisted around the leg at the ankle, the blue frock ornamented with red and yellow borders ; and to crown it, the smart cushion-shaped cap.

" I have several times attempted to photograph the